K^* dynamics in a nuclear medium*

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The K^* and the $\bar{K}^*$ are vector mesons that are composed of a light and a strange quark, i.e. the K^* is composed of a u and a $\bar{s}$ quark and the $\bar{K}^*$ is composed of a u and a s quark. We study the in-medium properties of these mesons in a dense and hot nuclear medium. The in-medium properties are based on chirally motivated models and these in-medium effects are parametrised as density or temperature dependent effective masses and widths. For broad in-medium particles we adopt the relativistic Breit-Wigner prescription, i.e. the spectral function

$$A_i(M,\rho_N) = \frac{\frac{2}{\pi}\cdot C_1 \cdot M^2 \cdot \Gamma_i^*(M,\rho_N)}{\left(M^2 - M_i^{*2}(\rho_N)\right)^2 + \left(M\Gamma_i^*(M,\rho_N)\right)^2}, \tag{1}$$

where C_1 stands for a normalisation constant, which is determined as the spectral function must fulfil the sum rule $\int_0^\infty A_i(M,\rho_N)dM = 1$, and $i = K/\bar{K}, K^*/\bar{K}^*$.

The in-medium effects are based on the complex self-energy obtained by solving the strange meson (off-shell) dispersion relation $E^2 - |\vec{p}^2| - M_i^2 - \Pi_i = 0$, i.e. the width of the spectral function is related to the imaginary part of the self-energy as

$$\mathrm{Im}\,\Pi_i(M,\rho_N) = -\Gamma_i^*(M,\rho_N)\cdot M \tag{2}$$

and the mass shift is related to the real part of the self-energy as

$$\mathrm{Re}\,\Pi_i(M_i^*,\rho_N) = M_i^2 - (M_i^*)^2 \tag{3}$$

(with M_i being the nominal mass in vacuum, i.e. $M_{K^*} = 0.892$ GeV). A vacuum width of $\Gamma_V^0 = 42$ MeV has been used throughout all of our calculations for the vector mesons.

We distinguish two scenarios for energies where the medium is dense and is filled with baryonic particles (FAIR; $\mu_B \neq 0, T \approx 0$) and when the medium is hot and filled with pionic particles (RHIC, LHC; $\mu_B \approx 0, T \neq 0$). The behaviour of strange vector mesons is different for these two media. Additionally the behaviour of a strange particle is different from the behaviour of a strange antiparticle in a dense nuclear medium, whereas it is the same in a hot nuclear medium (we are dealing with an isotopically symmetric pionic medium).

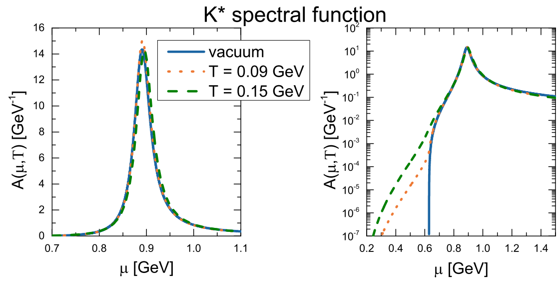

Figure 1: The K^* spectral function is shown as a function of the invariant K^* mass μ for different temperatures T. The blue solid line is for the vacuum case, the orange dotted line is for a temperature of $T = 0.09$ GeV and the green dashed line is for a temperature of $T = 0.15$ GeV. The same results are shown on a linear (left plot) and on a logarithmic (right plot) scale.

In figure 1 one can see spectral function for the K^* (and consequently the $\bar{K}^*$) in a hot, pionic medium. The effects of the medium are negligible, there is only a small mass shift and a very small broadening. However, when looking at the logarithmic plot one can see that the K^* gains some enhancement in the low mass region at temperatures $T > 0$.

For the K^* in a dense nuclear medium the width of the K^* decreases with increasing density since the kaon becomes slightly heavier as a result of the repulsive KN interaction. However, this is compensated by the repulsive self-energy from the K^*N interaction. The resulting K^* self-energy in a $t\rho$ approximation leads to a mildly repulsive K^* mass shift of about 5% (30 MeV) at a density of $\rho_N = \rho_0$. The change in the shape of the spectral function is negligible.

The major effects for the $\bar{K}^*$ in a dense nuclear medium come mainly from both the $\bar{K}\pi$ decay channel and from the highly inelastic $\bar{K}^*N$ interaction, leading to decay widths as large as 200 MeV at normal nuclear matter density $\rho_N = \rho_0$.

References

[1] Andrej Ilner, Daniel Cabrera, Pornrad Srisawad, Elena Bratkovskaya, *Properties of strange vector mesons in dense and hot matter*, Nucl. Phys. A 927 (2014) 249-265

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